HR Wallingford
Working with water

HRPP 321

A comparison of 1D and 2D flooding analysis from the Brechin case study

J. Gutierrez Andres & C. Rayner

Reproduced from a paper presented at
WaPUG Autumn Conference
Blackpool
7-9 November 2007

A COMPARISON OF 1D AND 2D FLOODING ANALYSIS FROM THE BRECHIN CASE STUDY

J. Gutierrez Andres[1] & C. Rayner[2]

[1] *HR Wallingford*
[2] *Wallingford Software*

1. Introduction to Brechin model

Following severe flooding on the River South Esk in Brechin in November 2002, a flood defence scheme was proposed by Angus Council. The proposed scheme involved constructing flood defences along the north bank of the river in Brechin (see Figure 1).

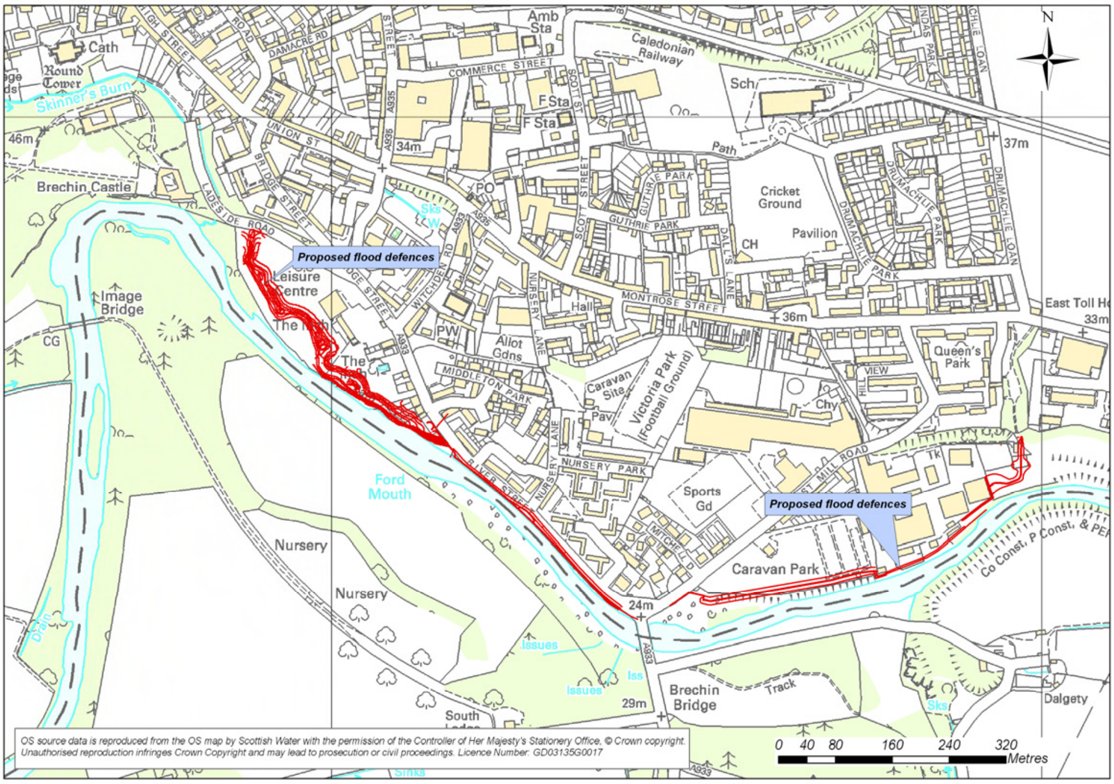

Figure 1 Layout of proposed flood defences

One of the main concerns about the proposed scheme was the likelihood of sewer flooding which would affect lower areas in Brechin since the river protection would prevent the flood water reaching the South Esk. Therefore as part of the Brechin Flood Alleviation Scheme, a pumping system was proposed to deal with excess stormwater and sewer flows that could not be discharged during periods of high river levels.

HR Wallingford was commissioned by Angus Council to carry out a drainage modelling study to estimate pumping station requirements to prevent flooding behind the flood walls and bunds. An existing calibrated model of the Brechin combined sewerage system provided by Scottish Water was used as the basis for this analysis.

The purpose of the modelling was to evaluate different pumping and detention storage scenarios.

Figure 2 (vertical exaggeration 10) shows that Brechin is a fairly steep catchment. Therefore to avoid unrealistic flooding in the upstream sections of the combined sewerage system and to ensure a conservative representation of the likely flows arriving at the critical flood area adjacent to the flood defences, an overland flow network was added to the model.

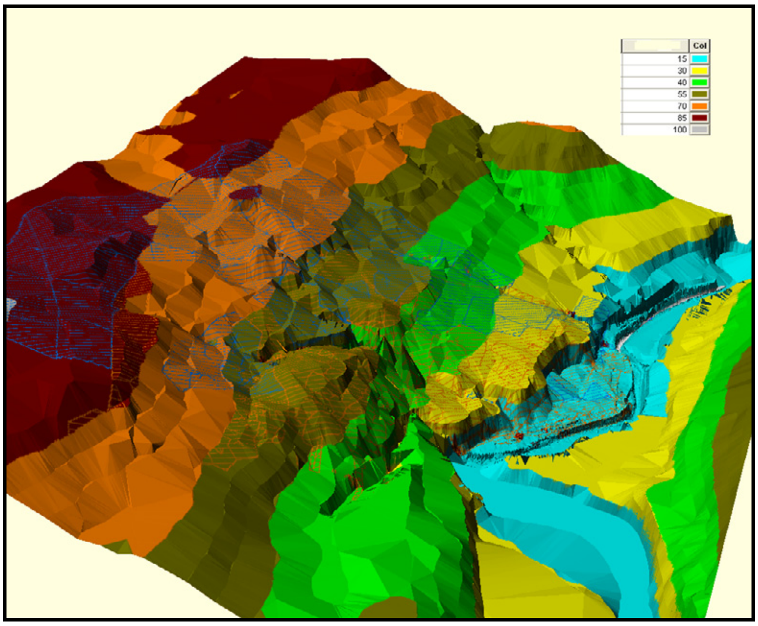

Figure 2 Brechin digital ground model (3D view)

1.1 1D Overland Flow Paths

The overland flow paths were based mainly on a 1D modelling representation of the roads as channels, 225mm deep and between 5 and 8 meters wide.

The study was commissioned before the release of InfoWorks CS2D therefore a 1D approach to overland flow routing and flood mapping was used. The use of other 2D modelling packages had the limitation of not allowing dynamic communication between surface modelling and pipe network modelling.

The roads that might act as overland flow paths were fully identified once a first set of simulations were undertaken and flooding locations identified. The usual procedure to define the overland network was by duplication of existing combined sewer pipes. The new invert levels were taken as equal to the sewer cover levels and the channel cross sections defined by an average width of a road. (Figure 3)

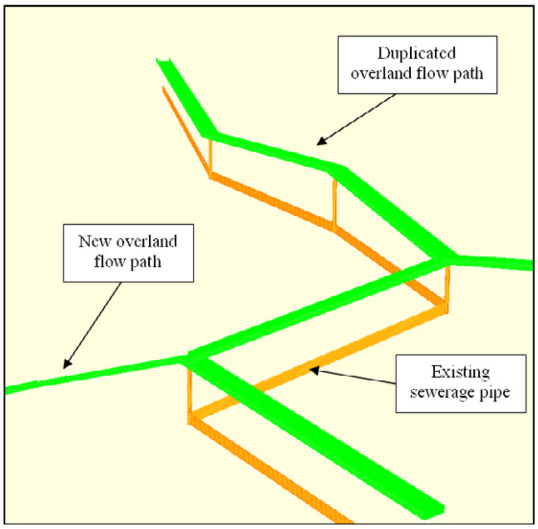

Figure 3 Overland flow path 3D detail view

The overland flow path network is generally connected to the combined sewerage system and flows are allowed to come back to the system when spare capacity is available. The manholes were set with a flood type of "stored" which has the geometry of a double cone.

The 1D flood mapping tool in IWCS was used to determine the areas that were likely to be affected by the flooding. All flooding manholes were defined as flood points. A flood depth is calculated at these points by subtracting the flood level from the ground model elevation. (Figure 4) This flood depth is then calculated throughout a flood compartment for multiple flood points using either a TIN or Inverse Distance Weighting (IDW) method.

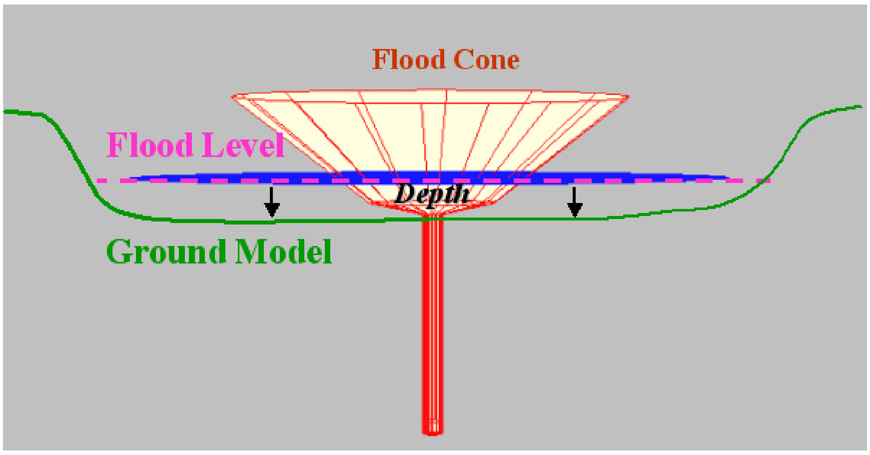

Figure 4 Diagram to illustrate 1D flood mapping

1D flood mapping can only provide an indication of where flooding will occur rather than any quantitative assessment. This is because, as shown in Figure 4, if the volume of the flood cone does not match the volume which exists above the ground model, then inaccuracies will occur. It is extremely difficult to accurately describe the storage available above ground using a combination of flood cones and overland flow links.

1.2 Conclusions from the original study

One of the main conclusions of the Brechin study was that the model predicted unrealistically high pump rates for the proposed pumping station that it was necessary to find an alternative solution. Reducing the pump rate by creating additional storage capacity was clearly an alternative but the volumes were very large and a more radical solution was proposed and investigated.

This option proposed the replacement of the downstream end of the main culverted stream with a pressurised pipe, which would both serve the main drainage and intercept overland flows for the upper section of the city (Figure 5). This solution reduced pumping rates significantly as there is sufficient head to discharge into the Esk South River regardless of the river water level. However, the solution is extremely sensitive to the assumption of flood pathways and connections to the culvert. Therefore, it was recommended that additional data, through further survey work, would provide greater confidence in the model results. This would be essential prior to proceeding to a detailed option assessment and design.

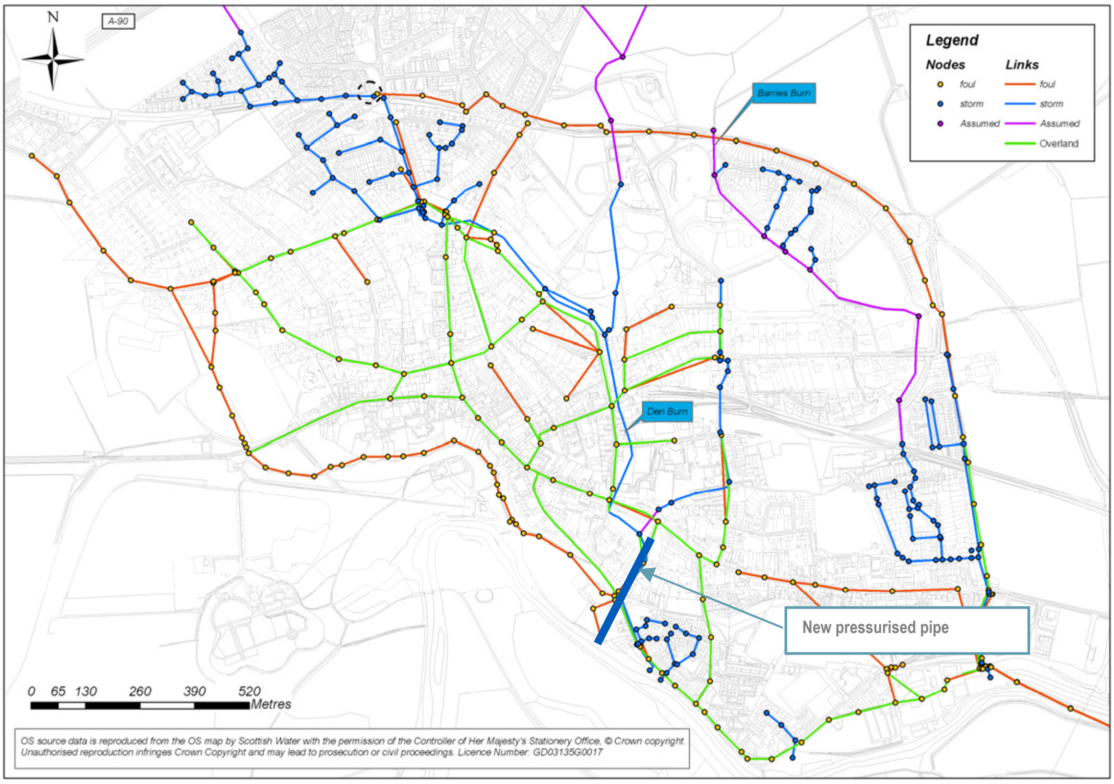

Figure 5 Alternative solution for Brechin Study

2. Conversion of the 1D model to 2D

Shortly after the submission of the first phase of the study, a 2D surface flow model was developed by Wallingford Software. This model was used by Wallingford Software and HR Wallingford as a case study to test the software and train staff in the use of IWCS 2D. It would also increase knowledge of the catchment and subsequently provide a better service to the client in the next project phase. This case study also allowed a comparison to be made between two very different flood-mapping approaches: 1D overland flow paths (as initially carried out for the project) with the new InfoWorks 2D flood spreading model.

All 1D overland flow links were removed and the flood type of the manholes was changed to 2D. This connects the 2D overland and 1D underground systems by means of a weir. (Figure 6)

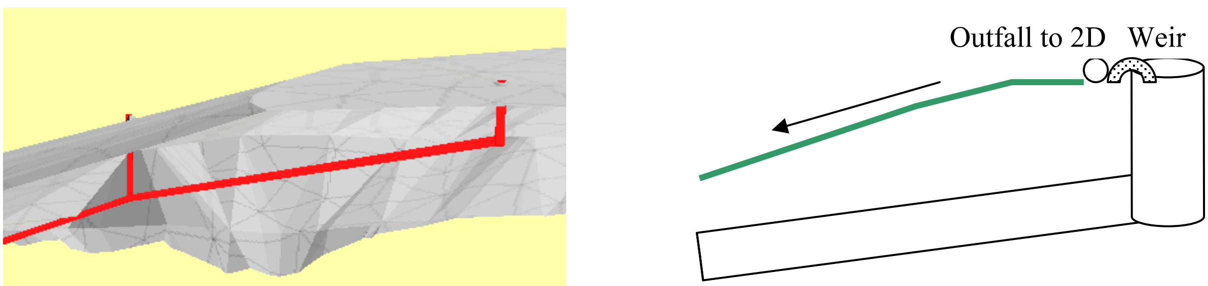

Figure 6 Schematic to show the connection between the underground 1D and 2D networks

The length of the weir is taken as the circumference of the manhole shaft and a coefficient of 0.5 was applied. A 2D mesh was constructed using the digital terrain model (DTM). Buildings were imported as polygons and modelled as voids so that flow could not penetrate them. (Figure 7)

A 100 year rainfall event was run through both models (old-1D and new-2D) under the following conditions:

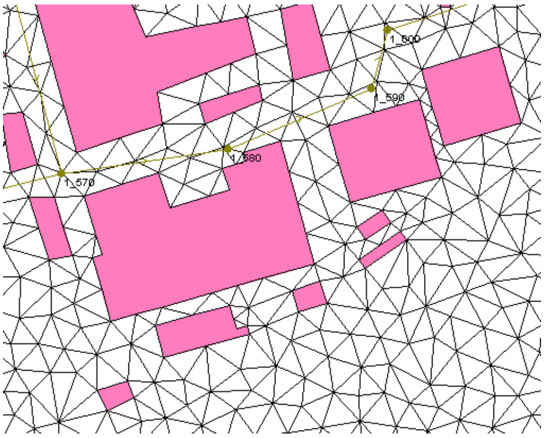

Figure 7 Meshing around buildings

Duration	1080 minutes
River levels	17 year return period
Pumping rate by the flood defences	None

3. Flood mapping comparison: 1D vs. 2D

Results showed unexpected differences in flood depths between the 1D and 2D simulations. The following comments discuss the reasons behind these findings.

Figure 8 shows a comparison between the 1D and 2D results at a particular time step. The results show a maximum depth of more than 1m for the 2D results and between 0.75 and 1m for the 1D. The first impression was that the difference was in part due to the buildings in the 2D model displacing the water, thus resulting in a higher depth as it was not practical to adjust the characteristics of the flood cones in the 1D model to replicate this displacement. However this reason by itself did not fully justify the depth differences observed.

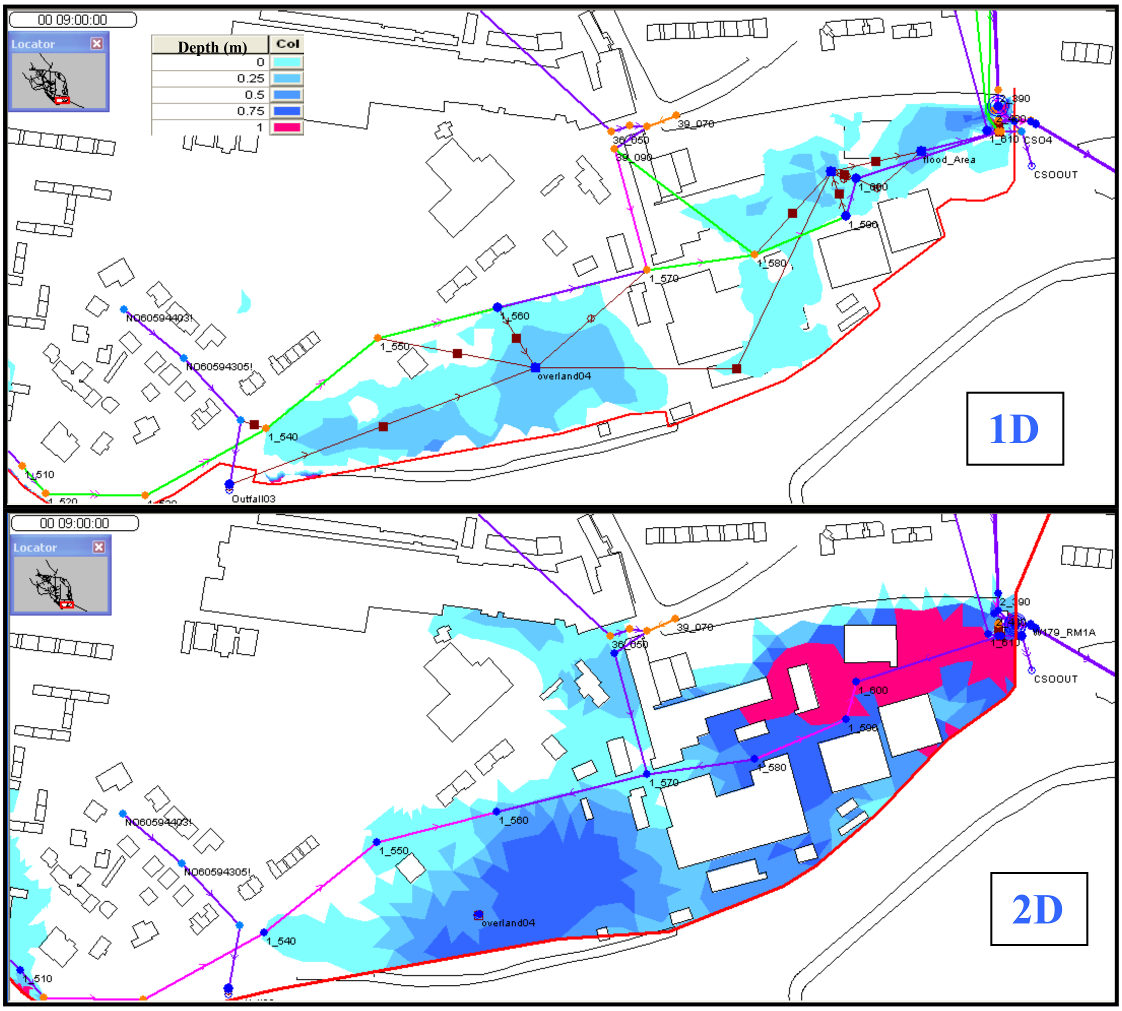

Figure 8 1D-2D comparison shows a higher depth with the 2D results

Another reason is that the 2D model automatically defines additional and more complex flow paths which did not exist in the 1D model. Figure 9 shows an additional flood route which was not represented in the 1D overland model. The identification of flood paths in the 1D approach is extremely difficult, especially in ponding areas. The 1D overland flow links do not take into account the variable nature of the geometry of the channel. It is difficult to define a channel shape that will represent the extent of the overland flow path. The 2D depths are again higher than in the 1D.

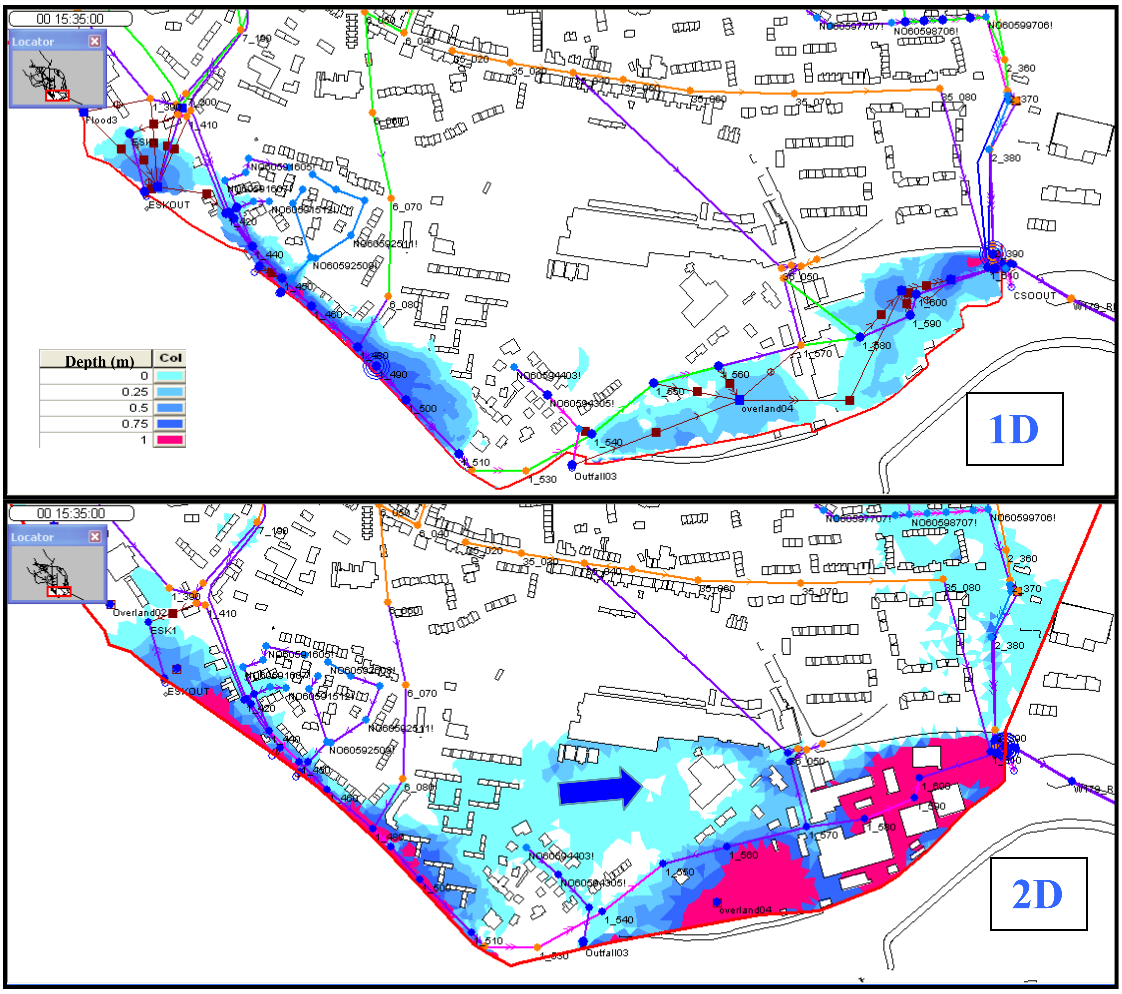

Figure 9 1D-2D comparison: Additional overland paths

Figure 10 shows how much care needs to be taken in defining overland flow paths by assuming they follow the same path as a road. It can be seen that there is an increase in elevation which has resulted in an overland link with a negative gradient. This can result in a large storage volume in the overland links upstream. Since the flood level is calculated at the nodes, the storage in these 1D links can result in the flood level not being correctly represented. This is because the floodable area would have been defined without taking into account storage in the overland links. This reason is another contributory factor in the depth differences observed.

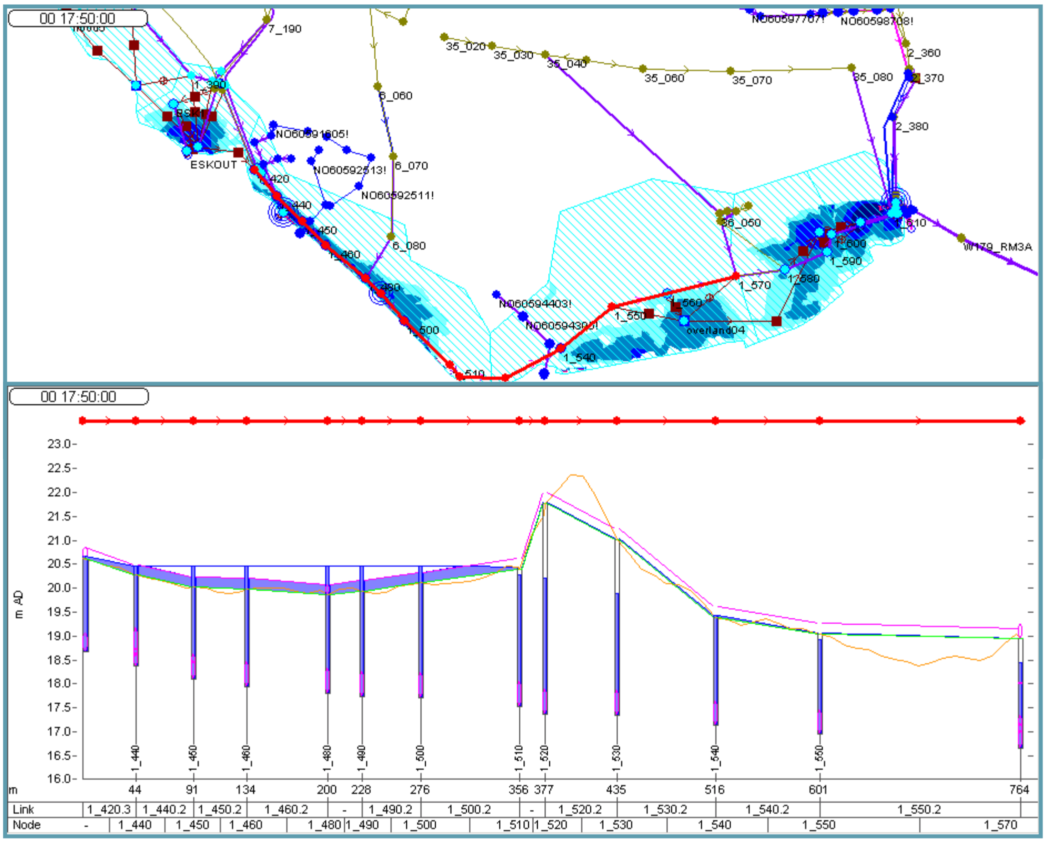

Figure 10 1D-2D Comparison: Storage in overland flow links

Figure 11 shows two very different flow routes at a junction when comparing 1D and 2D methods. For the 1D modelling the overland flow path was assumed to follow the road, (Figure 12) however the results from the 2D show that the flow disperses. The cause of this is shown in Figure 13 where it is evident that there is a high point in the ground model and therefore this would not realistically form a flow path. An assumption used by the 1D model is that the flow path has a uniform gradient between manholes. Figure 13 shows that this provides an erroneous path in this example. This example highlights the need for a good DTM supplemented by local knowledge, to form a full understanding of the flood processes.

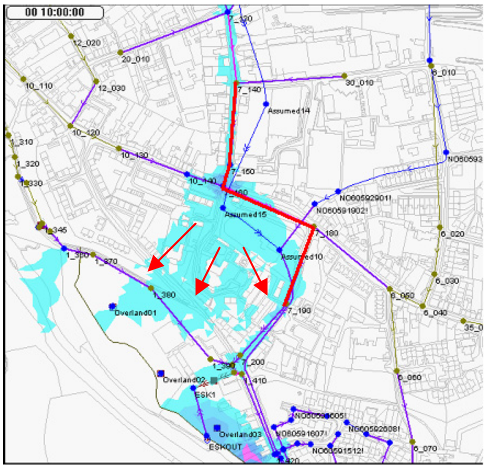

Figure 11 2D results

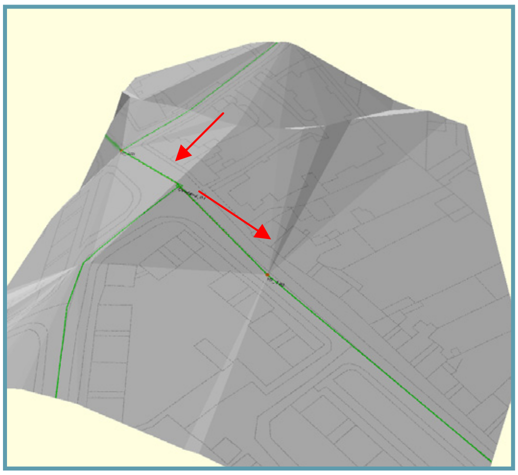

Figure 12 1D defined flow path

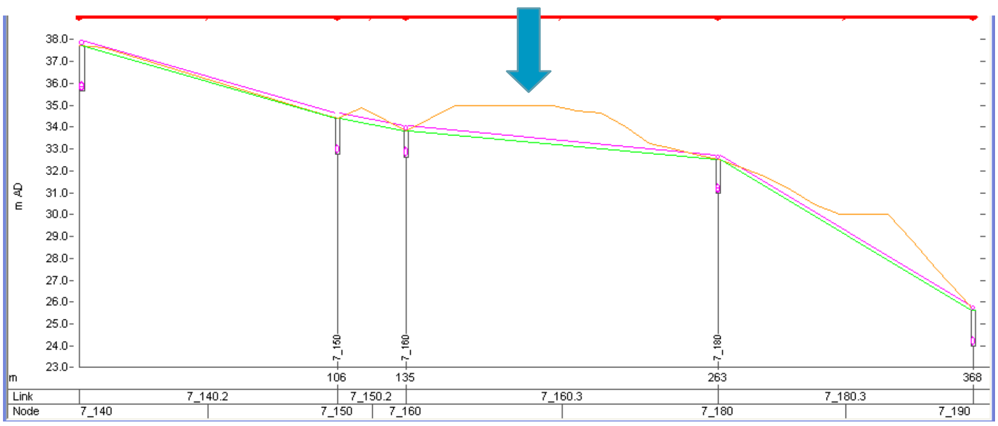

Figure 13 Cross section view

4. Conclusion

1D gave a good approximation of the flooding process and locations, although the model set up and construction was tedious and was based on a number of simplifying assumptions. Flood cones and links do not always accurately represent the storage on the catchment surface For example the definition of the flood cone shapes is never satisfactory in representing flood depth–extent relationships and trying to get these as accurate as possible requires a great deal of effort. The use of 1D overland link in ponding areas generates also additional storage that can reduces the extension of the flooding outline, and flow direction at road junctions has a certain degree of assumption.

The 2D model facility is a much more flexible approach although the requirement of data such as walls, buildings and detailed ground models is significant. InfoWorksCS 2D is a user friendly software, very quick to build and fully integrated with the below ground system. It gives a certain degree of confidence in the definition and identification of the overland flow paths that the 1D approach does not give.

The main conclusion of the comparison between 1D and 2D was consistently a higher prediction depth in the 2D. This can be partially explained from the reasons above, but it is believed that 2D allows a greater flood volume than the 1D, possibly due to the two methods being governed by different equations linking the surface and below ground systems. Both simulations were stable and consequently, there was no creation of volumes due to instability problems. 2D modelling is believed to be more realistic with fewer assumptions than 1D and in addition the definition of the flood extent is more conservative.

Surface modelling will always have a higher degree of uncertainty than below ground modelling where it is possible to calibrate model prediction with observed results. Historical flooding records, skilled modellers and a good understanding of the catchment will be essential in using InfoWorks CS 2D in an urban environment.

NOTES

Fluid thinking...smart solutions

HR Wallingford provides world-leading analysis, advice and support in engineering and environmental hydraulics, and in the management of water and the water environment. Created as the Hydraulics Research Station of the UK Government in 1947, the Company became a private entity in 1982, and has since operated as a independent, non profit distributing firm committed to building knowledge and solving problems, expertly and appropriately.

Today, HR Wallingford has a 50 year track record of achievement in applied research and consultancy, and a unique mix of know-how, assets and facilities, including state of the art physical modelling laboratories, a full range of computational modelling tools, and above all, expert staff with world-renowned skills and experience.

The Company has a pedigree of excellence and a tradition of innovation, which it sustains by re-investing profits from operations into programmes of strategic research and development designed to keep it – and its clients and partners – at the leading edge.

Headquartered in the UK, HR Wallingford reaches clients and partners globally through a network of offices, agents and alliances around the world.

HR Wallingford Ltd
Howbery Park
Wallingford
Oxfordshire OX10 8BA
UK

tel +44 (0)1491 835381
fax +44 (0)1491 832233
email info@hrwallingford.co.uk

www.hrwallingford.co.uk